Biological Evaluation of a Red Pine Plantation on the Allegheny National Forest

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Purpose and Need:

The Morgantown Field Office (MFO) received a request from the Marienville Ranger District, located on the Allegheny National Forest (ANF), to evaluate the cause(s) of mortality in a red pine (*Pinus resinosa*) plantation. This request came from the District Silviculturist, Jerry Jordan, who recently observed an increase in red pine mortality. This evaluation was undertaken by the MFO to address this request but also to identify any significant problems that might possibly affect other red pine plantations within the ANF.

This plantation was sold 3 to 4 years ago and the purchaser intended to start logging this winter, until becoming aware of the increased pine mortality. The purchaser is concerned with the current level of mortality and how a delay in harvesting will affect future mortality within the plantation.

Project Location/Description:

The red pine plantation is located in McKean County, Pennsylvania 5 miles northwest of Kane, just off route 6 on the Allegheny National Forest (Figure 1), and was established by the Civilian Conservation Corps (CCC) around 1940. It covers ~ 23 acres, and is composed of red pine and Norway spruce (*Picea abies).* The plantation is laid out in a north-south direction, with red pine and Norway spruce alternating within each row. Tree spacing within rows was difficult to determine because the southern half of the plantation was thinned at some point in the past, residual tree spacing ranges between 8 and 27 feet.

This plantation was evaluated by the MFO in 1998. This evaluation found that the plantation was suffering from red pine pocket decline syndrome (MacKenzie 1998); a syndrome that involves mortality pockets of red pine caused by a complex of insect and disease agents. In the classic model this decline is characterized by expanding circular areas of dead and declining trees (Klepzig et al. 1991). The previous evaluation found that the mortality observed did not follow the classic model and offered an alternative model for the mortality observed. This evaluation also recommended that the ANF remove any trees with fading crowns.

Project Objectives:

The objectives for this biological evaluation were to: (1) investigate the cause(s) of mortality occurring; (2) determine the approximate rate of mortality in order to assess the urgency of a timber harvest in the near future; and (3) provide management recommendation(s) based on red pine silvics and the rate of mortality.

Figure* 1*: Red Pine Plantation, Compartment 819 - stand 28, Allegheny National Forest.

Project Methods:

In December 2010, the red pine plantation was sampled by strip cruising. In total, 4 strips ten feet wide were implemented across the 23 acre plantation. The strips were spaced approximately 164 feet apart and oriented in an east-west direction. They varied in length, ranging from 950 to 1700 feet due to the irregular shape of the plantation. The starting point for each strip cruise was found using a global positioning system (GPS) unit, a compass bearing was shot from the boundary of the plantation and a hip-chain was used to mark the center of each strip. All trees that fell within five feet on each side of the centerline were included in the cruise. Within each strip, species, diameter at breast height (DBH), crown class and crown condition (crown density, color, and dieback) were recorded for all standing trees. Each tree was categorized based on a 7-point condition class system, ranging from healthy and living to a cut stump (Table 1) to qualify the rate of mortality over time.

Insect and disease activity was assessed by a visual survey across the plantation and by cutting several dead and dying trees. Root disease activity was assessed by excavating around the base of trees and around roots. The spatial pattern of mortality was assessed by plots from a referenced (GPS) plot center. The azimuth angle and distance to each live, standing dead, and downed tree (or stump) were recorded using a compass and loggers tape. Species, DBH, crown class, crown condition, and tree condition class were recorded for each tree within the plot (Moeur 1993).

Table 1: Dead and dying tree condition class based on retention of needles and branches, Allegheny National Forest, Kane, Pa.

Condition class	Code	Estimated time since death*
1	Living/Healthy	--
2	Fading/dying	current
3	Dead with needles	1-2 yrs
4	Dead with fine branches	>2-5 years
5	Dead with large branches only	>5-7 years
6	Dead with no branches	>7 years
7	Cut stump	>25 years

*Derived from Forest Inventory and Analysis guidelines (USDA 2001)

Data Analysis:

Data was compiled across the 23 acre plantation according to tree condition by species and size. Individual tree basal area was determined using the constant .0054542 multiplied by diameter at breast height (DBH) squared. Basal area was summed by species for each strip, divided by the area sampled, and then multiplied by a per acre conversion factor. Basal area was calculated for all species. Trees per acre (TPA) were determined for each species in the plantation. This number was calculated by taking the number of stems within the area sampled, divided by the area sampled, and then multiplied by the per acre conversion factor. The quadratic stand diameter (QSD) was calculated as the square root of the sum of the diameters at breast height (4.5 feet above ground) of each individual tree, divided by the total number of trees (Curtis et al 2000). Diameter at breast height for red pine was estimated using the stump diameter (inside bark) and the equation (Wharton 1984):

$$y = -0.80166 + 1.00648x$$

Where:

Y = diameter at breast height in inches,

X = stump diameter in inches (inside bark).

Project Results:

Species composition and basal area

The overstory canopy is dominated by red pine, with Norway spruce being primarily in the intermediate and overtopped crown classes. Total basal area including living and standing dead trees in the plantation was 221.6 ft²/acre with a stem density of 361.1 TPA and a QSD of 10.6 inches. The living basal area was 173.3 ft²/acre with a stem density of 290 TPA and an average QSD of 10.5 inches (Table 2). Red pine accounts for 128.6 ft²/acre of basal area with a density of 89.7 TPA and a QSD 16.2. Norway spruce basal area at 66.3 ft²/acre and 147.8 TPA (Table 3) with QSD of 9.1 inches, other species accounting for an additional 21.5 ft²/acre of basal are with a density of 120 TPA and a QSD of 5.7 inches, this includes patches of American beech (*Fagus grandifolia)*, as well as scattered patches of black cherry (*Prunus serotina*), and serviceberry (*Amelanchier arborea*).

Table 2: Average diameter(± SD), basal area and density of living and dead stems for red pine (*Pinus resinosa*)***, compartment 819 – stand 28, Allegheny National Forest, Kane Pennsylvania.***

strip #	Living			Dead		
	Avg DBH (in)*	BA (ft^2/ac)	TPA	Avg DBH (in)*	BA (ft^2/ac)	TPA
1	17.5 ± 2.42	118.4	69.4	15.4 ± 3.19	74.9	55.5
2	18.1 ± 0.96	28.3	15.8	15.3 ± 2.15	82.4	63.4
3	15.2 ± 4.55	114.4	83.1	15.2 ± 3.67	23.4	17.6
4	15.5 ± 2.25	75.2	56.5	16.3 ± 1.75	35.3	24.2
Avg*	**15.9 ± 3.58**	**85.7 ± 41.9**	**56.2 ± 29.04**	**15.5 ± 2.61**	**54 ± 29.03**	**40.2 ± 22.7**

Mortality

Total standing dead basal area in the plantation was 48.4 ft²/acre with a stem density of 71.1 TPA and QSD of 10 inches. The majority of the mortality observed was in red pine. Red pine mortality represented 89 percent of the total basal area and 43.2 percent of the TPA of standing dead. Norway spruce mortality in contrast represented 6.3 percent of the total basal area and 20.5 percent of the TPA of standing dead.

The diameter distribution for standing dead trees along with their condition class (Figures 2 and 3) was used to estimate time of death and to assess mortality trends within the plantation. Differences in average DBH between tree condition classes supported the estimated elapsed time since death. The majority of red pine mortality 36 and 29 percent was present in condition classes 5 and 6, respectively. It is estimated that these trees died more than 5 years ago. Since

then mortality has decreased (Figure 4). Current mortality as represented by fading and dying trees makes up 2 percent of the mortality and accounts for ~ 1 TPA. Eighty-eight percent of the mortality observed in Norway spruce occurred in the last 1 to 2 years, with no trees currently showing any signs or symptoms of imminent mortality (Figure 4).

Thinning

The average stump size for removed stems was 11.9 inches. Estimated DBH for these felled trees at the time of cutting is 11.2 inches. Based on the size, condition of the stumps, and the lack of felled material and slash, and using an estimated growth rate of 0.8 inches/decade. The plantation was likely thinning 30 to 40 years ago. For reasons that are unknown the thinning was confined to the southern half of the plantation and accounted for the removal of 4.8 TPA.

Table 3 Average diameter(± SD), basal area and density of living and dead stems for Norway spruce (Picea abies), compartment 819 – stand 28, Allegheny National Forest, Kane Pennsylvania.

strip #	Living			Dead		
	Avg DBH (in)*	BA (ft^2/ac)	TPA	Avg DBH (in)*	BA (ft^2/ac)	TPA
1	8.5 ± 3.54	84.4	184.9	3.2 ± 1.27	0.6	9.2
2	8.4 ± 4.39	75.2	154.4	3.8 ± 1.08	1.9	23.8
3	8.9 ± 3.35	53.0	105.8	16	3.5	2.5
4	8.5 ± 3.60	56.2	121	4.0 ± 2.20	2.4	21.5
Avg*	**8.6 ± 3.70**	**67.2 ± 15.08**	**141.5 ± 35.33**	**4.5 ± 3.38**	**2.1 ± 1.2**	**14.3 ± 10.12**

Spatial pattern

Mortality and growth response varied by location within the plantation. Mortality was highest in the southern part (strips 1 and 2) of the plantation with dead basal area ranging between 73 to 82 ft^2/acre for red pine, and 1 to 2 ft^2/acre for Norway spruce. The increase in mortality in this part of the plantation was offset by an increase in the average DBH of the remaining red spruce (Table 2). The northern part of the plantation (strips 3 and 4) had lower mortality level for red pine and a higher mortality level for Norway spruce (Table 1 and 2).

Stem plots established to assess mortality patterns showed no consistent mortality patterns (Figure 5). Red pine mortality was not consistent with typical symptoms of red pine pocket decline syndrome. Normal red pine decline symptoms include an area of dead trees, ringed by trees showing reduced diameter and height growth (Klepzig et al.1991). This was not

the case for compartment 819 – stand 28, as mortality was erratic and inconsistent. Small pockets were occasionally present; however it was not uncommon for live red pine trees to be located in these pockets. Figure 5 represents an example of one mortality pocket within the plantation.

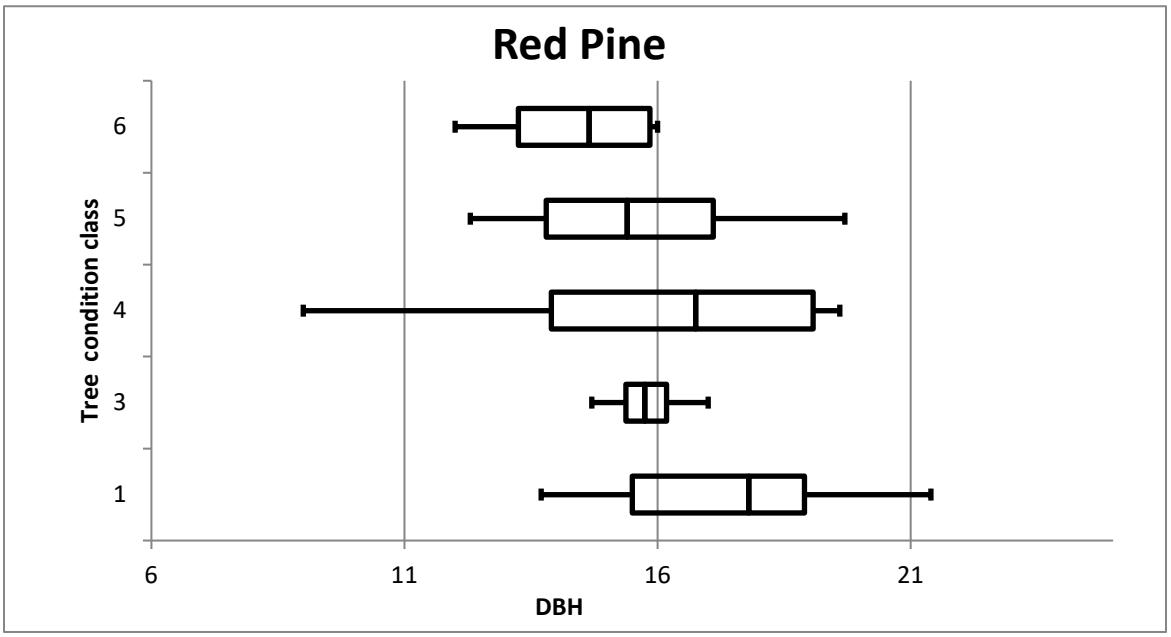

Figure 2: Red pine diameter distribution by tree condition class, compartment 819, stand 28, Allegheny National Forest.

Insect, disease and wildlife activity

A number of damaging agents, as well as symptoms of red pine decline were observed within the plantation. Blue and black wood stains, caused by the fungi *Leptographium spp*. and *Ceratocystis spp*.were observed in standing and felled trees, along with the shoestring root rot (*Armillaria spp*). Fruiting bodies of the red belt fungus (*Fomitopsis pinicola*) were observed throughout the plantation on red pines. Annosus root rot (*Heterobasidion annosum*) was not detected within the plantation. Bark beetle, (*Ips spp.*) activity was observed in the crowns and boles of dead and dying trees. No red turpentine beetle (*Dendroctonus valens*) activity was observed, although the previous evaluation did mention their presence at low levels.

In addition to the red pine damage from insects and disease, damage to the terminal shoots of Norway spruce were observed across the plantation. This damage is believed to be caused by squirrels. In pine plantations, it is common for squirrels to cut off the leader shoots in order to feed upon the cluster of buds or sometimes the top branches (Mills 1938). These Norway spruce terminal shoots were observed all across the plantation forest floor.

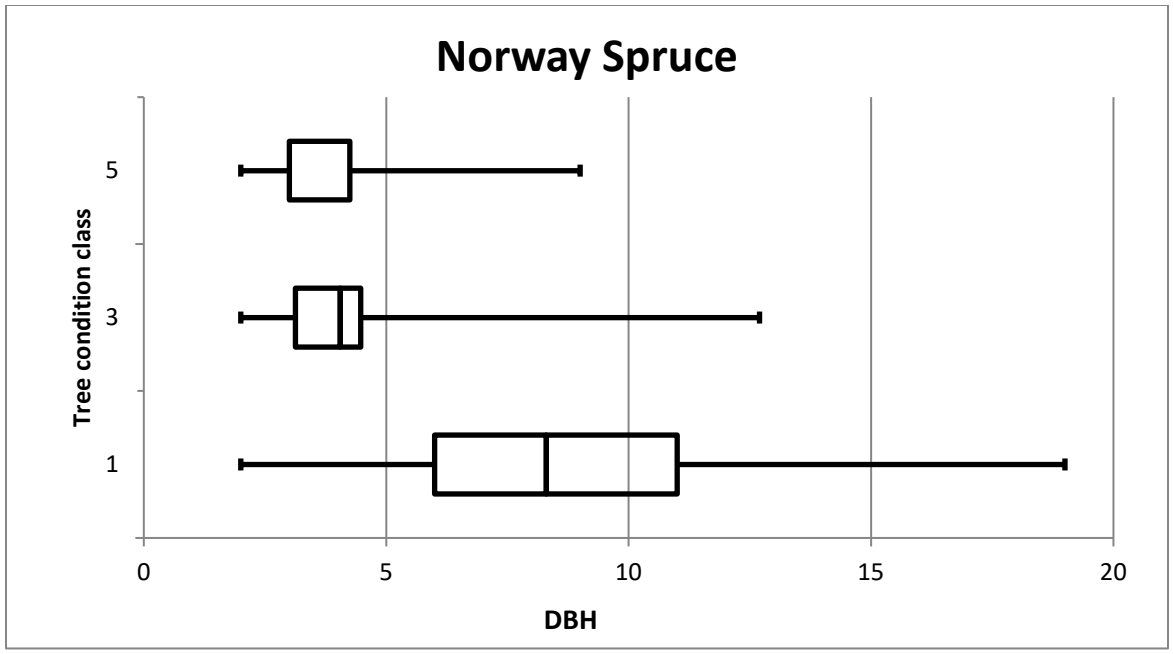

Figure 3: Norway spruce diameter distribution by tree condition class, compartment 819, stand 28, Allegheny National Forest.

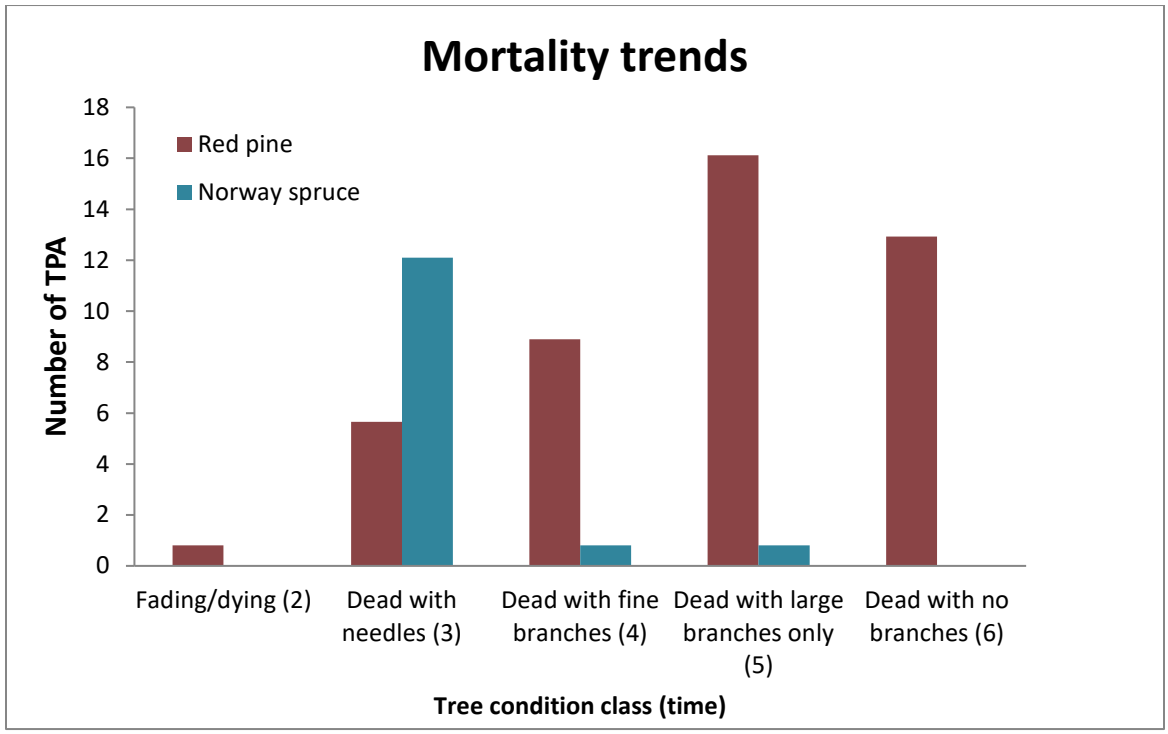

Figure 4: Number of TPA for dead and dying red pine trees in each tree condition classes, compartment 819, stand 28, Allegheny National Forest.

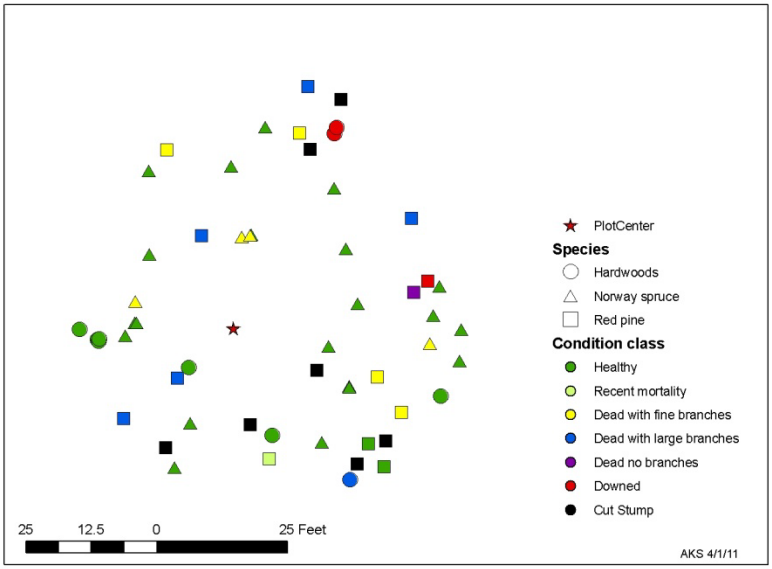

Figure 5. Stem plot of a mortality area within the red pine plantation, compartment 819, stand 28, Allegheny National Forest. Stem plot used to look for patterns of tree mortality. Classic red pine pocket decline characterized by expanding circular area of dead and declining trees.

Discussion

The main objectives of this evaluation were to assess the causes and rate of mortality on this red pine plantation. Although numerous insects and diseases are present and active within the plantation the mortality observed appears to be primarily the result of overstocking and stand stagnation. The current rate of mortality is lower now, than in the past (Table 4). This cycle of self thinning will continue within the plantation, as resources again become limiting.

Red pine is a long-lived species; however tree growth can become retarded if proper spacing conditions are not met. Height growth of dominant red pine was retarded after spacing became closer than 15% of height (Burns and Honkala 1990). On good sites, red pine basal area growth ceases when the stand reaches a level of about 250 ft²/acre (Burns and Honkala 1990). For this discussion we will assume that this mixed plantation is going to behave as a red pine plantation. In general, plantations can become stagnant if overstocked. Ideal stocking density for red pine is normally around a level of 80%, however compartment 819 – stand 28 currently has a living basal area of 173.3 ft²/acre with a stem density of 290 TPA and an average QSD of 10.5 inches making it at a stocking level of more than 90%.(Figure 4). When factoring in dead basal area per acre and trees per acre, the basal climbs to 221.6 ft²/acre with a stem density of 361.1 TPA and a QSD of 10.6 inches raising the stocking density to more than 100% (Benzie 1977). This indicates that approximately 5 to 7 years ago the plantation was overstocked and red

pine growth across the plantation was stagnant. During this period of stagnant growth, red pines were likely stressed from competition for available nutrients and became susceptible to insect/disease attack, drought, and self-thinning. According to the Palmer Drought Severity Index for Pennsylvania, a moderate drought event occurred in the state approximately 8 to 10 years ago. This might have very well triggered the mortality event 5 to 7 years ago.

Red pine is relatively intolerant of shade, on a scale of 1 to 10, with 1 being highly intolerant and 10 very tolerant, red pine is rated as a 2.4 (Burns and Honkala 1990). On the other hand, Norway spruce is a shade tolerant species, which allows it to survive in the understory. Currently, the majority of mortality has occurred in the southern portion of the plantation. In this area, quadratic mean diameter for red pine is almost 2 inches greater than the trees in the northern portion of the plantation. This supports the assessment that the plantation has started to naturally thin and release dominant red pines. Since the northern portion does not have significant mortality and has a smaller QMD, it is likely that this part of the plantation is currently stagnant and in a "stressed" state, which likely means that this portion of the plantation will see an increase in mortality in the near future.

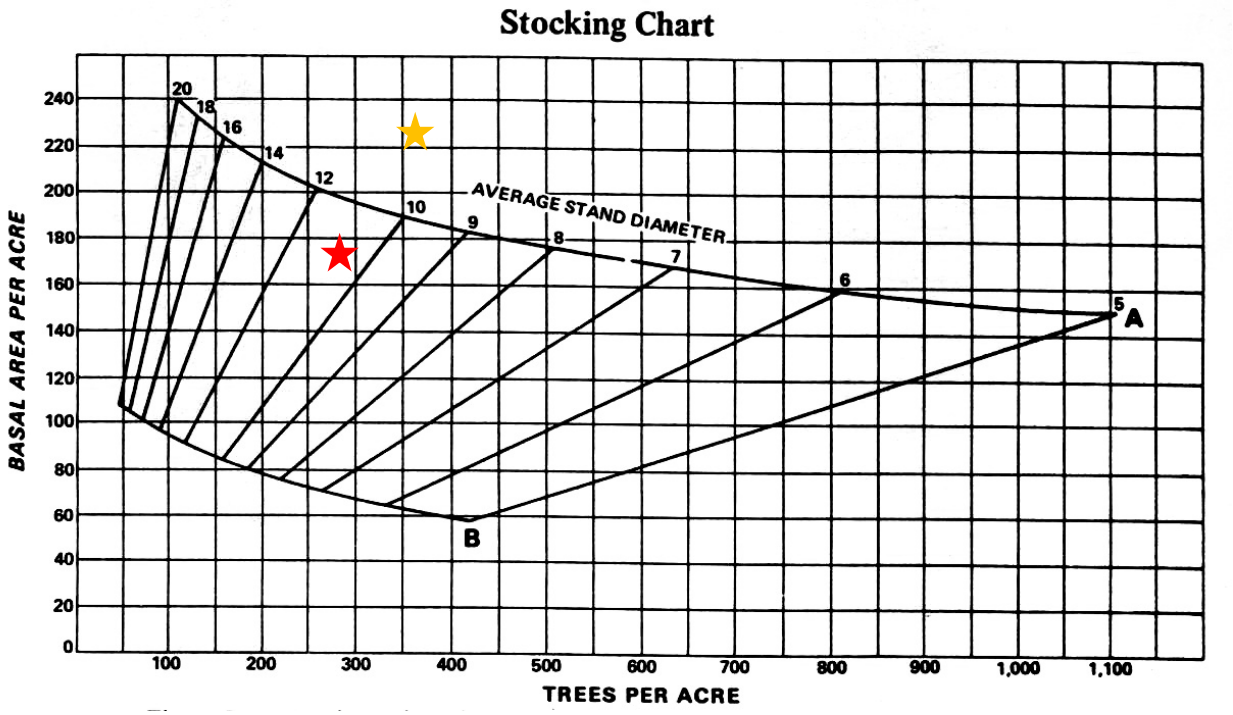

Figure 4. ***Stocking chart for red pine*** **(Benzie 1977).** ***The red star is the current stocking level; the gold star is the estimated stocking level before mortality.***

Another factor to consider is the natural range of red pine. This plantation in McKean Co. is located on the southern fringe of the red pine range (Rudolf 1990). Naturally, red pines prefer areas with cool-to-warm summers and cold winters and low to moderate precipitation

(Burns and Honkala 1990). In the case of the plantation, the climate may be slightly too warm for optimal red pine growth.

Red pine decline

A serious threat to red pines within its range is the syndrome referred to as red pine decline. Red pine decline was first reported in 1975 in several states around the Great Lakes region. The most common symptom includes large circular areas (pockets) of mortality, followed by rings of trees that show reduced diameter and height. Trees along the margin of the pocket may possess thin crown, whereas trees further from the stand appear to be vigorous and healthy with full crowns. Stands declining form this syndrome are usually accompanied by symptoms characteristic of several insects and fungal species. These species include various stem and root-infesting beetles, and the black and blue staining fungus.

Although mortality was observed in a "clump" or "pocket" pattern, no conclusive evidence of red pine decline was present. Characteristics consistent with red pine decline were inconclusive and inconsistent. However, various beetles and fungi associated with red pine decline, including *Ips*, as well as Armillaria and blue and black stain were present across the plantation. These damaging agents are believed to be secondary causes of mortality in this plantation.

Another factor thought to be a potential cause of mortality in red pine decline is Annosus root rot. This disease commonly invades a stand after thinning operations. Field identification for Annosus is commonly observed through large pockets of mortality. The roots of an infected tree will be shredded and stringy. Occasionally, fruiting bodies will become visible on infected trees. No conclusive evidence of Annosus root rot was found during this evaluation or the previous evaluation. Shoestring root rot, a common root disease in the United States, was present within the plantation. Dark, root-like fungal structures called rhizomorphs were observed at the base of dead red pines. It is believed that the shoestring root rot is not the primary cause for mortality in the plantation; however it may have caused red pines to become further weakened and stressed.

Management Alternatives

Three basic management alternatives are briefly discussed below to assist managers in selecting alternatives to best meet the overall objectives of this stand and the management area.

Management Alternative 1: Implement thinning, harvest later.

This management would release the current plantation and reduce future mortality, and promote overall growth.

If a thinning operation is implemented as soon as possible, future mortality could be prevented. Considering the stocking density of the plantation and the high level of competition for available water and nutrients, a thinning will release the dominant red pines and should reduce the rate of mortality. However, it is possible that higher rates of mortality could persist on the margin of current mortality pockets. Ideally, the plantation needed to be thinned 15 to 20 years ago. Regardless, the plantation has naturally thinned itself and will continue to do so if no further action is taken. The response to a thinning might not be significant considering the age of the plantation, however overall vigor, along with growth should increase, especially in the upper portion of the plantation.

In order to attain the best results for this plantation, a crown thinning should be implemented. This should yield the greatest response in plantation growth and vigor. After this thinning, the plantation should be harvested in 20 to 30 years. At this point, the plantation would have recovered from stressed conditions and reached maturity.

Management Alternative 2: Harvest Plantation

A complete timber harvest could be implemented. The typical timber harvest prescribed for a mature red pine plantation is a complete overstory removal. Red pines are usually managed to be an even-aged stand, and this plantation is no exception. However, considering that this stand was either poorly managed or not managed at all, maximum timber value wouldn't be attained until the stand is 120 years of age. For this to remain as a red pine plantation, artificial regeneration will be required.

Management alternative 3: No action

The third alternative involves no action at all. If this happens, it is likely the plantation will remain stagnant for a short time and then higher rates of mortality will persist relative to alternative one. This is due to the plantation naturally self thinning.

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Other information available at:

http://forestandwildlifeecology.wisc.edu/extension/Publications/82.PDF